Title: The introduction of South-Western Asian domesticated plants in North-Western Africa: an archaeobotanical contribution from Neolithic Morocco

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Abstract

This paper focuses on the new macro-botanical evidence of South-Western Asian cultivated plants from northern Moroccan Neolithic sites. Due to the reduced presence of plant remains from previous excavations in the region, archaeological evidence of agriculture is rare and the arrival of domesticated plants and the role of farming in the Early Neolithic of North Africa are still poorly understood. Here we present results of the analysis carried out in three sites recently excavated: Kaf Taht el-Ghar, Khil, and Ifri Oudadane. Charred seeds of domesticated cereals (*Triticum dicoccum*, *T. monococcum/dicoccum*, *T. aestivum/durum*, *Hordeum vulgare, H. vulgare* var. *nudum*) and pulses (*Lens culinaris, Pisum sativum, Vicia faba*) have been recorded in all sites analyzed. Differences in the proportions of the main crops identified were found in the various sequences analyzed, with a marked decrease in crop diversity between 4500-4000 cal. BC that may suggest a shift in agricultural practices. Radiocarbon dating of crop seeds indicates that farming, along animal herding and pottery, was most probably introduced in the region at the interval between 5500-5000 cal. BC. Absence of evidence for Neolithic farming in other regions of North-Western Africa suggests that

the first crops arrived into Morocco through a maritime route, more likely from the Central or Northern Mediterranean shores. Similarities in both radiocarbon dates and crop assemblages from early Neolithic sites in Northern Morocco and the south of the Iberian Peninsula point to an almost simultaneous East to West maritime spread of agriculture along both shores of the Western Mediterranean.

Keywords

Neolithic, Morocco, Archaeobotany, Agriculture, Domesticated plants

1. Introduction

The introduction and spread of domesticated plants to North-Western Africa during the Neolithic period is a topic that has received little attention until very recently due to the lack of macro-botanical remains. Most of the Neolithic sites in this region were excavated during the first part of the 20th century, when systematic recovery of plant remains and radiocarbon dating were not fully developed. As a result, archaeological evidence of agriculture is rare, and the arrival of domesticated plants and the role of farming in the Early Neolithic of North Africa are still poorly understood (Barich, 2014; Barker, 2002, 2006; Garcea, 2004; Marshall and Hildebrand, 2002; Roubet, 1979).

According to published data, agriculture in North Africa may have spread following different paths (Barich, 2014; Linstädter, 2008). In north-eastern Africa, domesticated plants were probably introduced from the Near East through Egypt during the 5th millennium cal. BC (Wendrich et al., 2010; Zohary et al., 2012), although evidence from recent phytoliths analysis from Sudan suggests that the arrival of Near Eastern cereals was probably earlier, between 5000-4500 cal. BC (Madella et al., 2014), spreading much later (3rd millennium cal. BC) to Libya (Barich, 2014; Pelling, 2008; Van der Veen, 1995).

In North-Western Africa current data indicates that crops along domestic animals and pottery were introduced by a different route. Results from two recently published datasets from the sites of Ifri Oudadane (Morales et al., 2013) and Kaf Taht el-Ghar (Ballouche and Marinval 2003), in northern Morocco, have yielded clear evidence of farming in the form of seeds of domesticated cereals and legumes, pointing to the practice of farming since the middle-late 6th millennium cal. BC. However, the available data comes from northern Morocco and cannot be applied to other countries of the region. From the rest of Morocco, Tunisia and Algeria remains of domesticated plants from Neolithic sites are absent, although domesticated animals and pottery are recorded in several sites (Aouadi et al., 2014; Kherbouche et al., 2014; Linstädter, 2008; Linstädter et al., 2012).

For the time being, three main hypotheses have been proposed regarding possible routes of arrival of the Neolithic package to Morocco. The first states that agriculture together with the whole Neolithic package arrived initially to the Iberian Peninsula, and from there it moved south through the Gibraltar Strait (Martins et al., 2015; Zilhâo, 2014). The second advocates the transfer of some traits related to pottery, flint technology and bone tools from North Africa to the Iberian Peninsula (Cortés-Sánchez et al., 2012; Manen et al., 2007; Marchand and Manen, 2010). The third suggests that the Neolithic package was spread by seafarers who synchronously arrived to both the

northern and southern shores of the Western Mediterranean (Gilman, 1974; Linstädter et al., 2012).

In this paper, we contribute to this interesting topic by presenting the results of the analysis of the macrobotanical remains (seeds and fruits) from three recently excavated Neolithic sites from Morocco: Kaf Taht el-Ghar (KTG from now on), Khil and Ifri Oudadane. Plant remains can be accurately identified and directly dated by radiocarbon methods, and they provide one of the most precise evidence of the presence of crops in archaeological sites. On the other hand, Morocco is located at the westernmost side of the Mediterranean shore and it represents a critical zone for understanding the spread of agriculture in North-Western Africa, with implications for surrounding areas including the European Mediterranean and the Sahara (Oliveira et al., 2012). Here we use this new dataset in order to answer the following research questions: (1) When did domesticated plants first appear in the region? (2) What was the route or routes of arrival of domesticated plants to the area?

2. Environmental setting and description of the sites

2.1 Environmental setting

The study area is located in Northern Morocco (Fig. 1). Ifri Oudadane and KTG are situated along the Mediterranean coast, while Khil is set in the Atlantic coast. The area occupied lies between the sea and the Rif Mountains. Present-day climate is Mediterranean with hot summers and mild winters, and a wet season between autumn and spring. The flora of the area belongs to the maquia-forest type made of shrubs and small trees such as mastic trees (*Pistacia lentiscus*), pines (*Pinus halepensis*), araar (*Tetraclinis articulata*), junipers (*Juniperus* spp.) oaks (*Quercus* spp.) and wild olives (*Olea europaea*) (Charco, 2001; Fennane et al., 2007).

Environmental conditions have changed significantly during the Holocene in North Africa, especially in the Sahara (Garcea et al., 2013; Manning and Timpson, 2014; Mercuri et al., 2011). In Northern Morocco, pollen and charcoal analyses carried out in several Neolithic sites indicate that conditions were more humid during the early Holocene than at present time, with a wooded environment that included evergreen sclerophyllous oaks and riparian forests (López et al., in press; Zapata et al., 2013). However, after 4600 cal. BC, conditions become drier and riparian taxa disappeared or decreased. After 4000 cal. BC, this process led to an arid or semi-arid environment, similar to that of the present-day. The impact of human activities, including agriculture and animal herding, is recorded since 5600 cal. BC, causing the decline of arboreal components and the increase of shrubs and grasses (López et al., in press; Zapata et al., 2013).

2.2 Description of the sites

Kaf Taht el-Ghar

KTG is located in the Tangier region of Morocco, at 410 m above the sea level and 9 km from the current seashore. It is a large cave through a limestone bedrock containing several chambers and channels (Fig. 2). The ‘main chamber’, of ca. 20 x 10 m, has been the focus of several seasons of excavation. The first works were undertaken in 1955 by the Spanish archaeologist M. Tarradell (Tarradell, 1957-1958), and later,

between 1989 and 1994, by a Moroccan-French team (Ballouche and Marinval, 2003; Daugas and El Idrissi, 2008; Daugas et al., 2008; El Idrissi, 2001). The materials analyzed in this study come from the new excavations carried out at the 'main chamber' in 2012 by a Spanish-Moroccan team within the framework of the AGRIWESTMED project funded by the European Research Council.

Three trenches were opened during the 2012 season. The first (26 A-B) covered Epipalaeolithic and Early Neolithic layers with Classic and Mediaeval levels in the upper part of the stratigraphy (Fig. 2). The second trench (26 G) spans from the Iberomaurusian (Late Stone Age) to the Early Neolithic. The third trench (26 HI-26 JK) records an occupation that initiates in the Epipalaeolithic and continues during the Middle Neolithic. The top layers contain materials from Chalcolithic and later periods.

Levels dated to the 6th millennium cal. BC from all the trenches contained abundant lithic tools of lamellar technology, along with Impressed-Cardial ware and Channeled ware. Evidences of domesticated animals, especially goat (*Capra hircus*) and sheep (*Ovis aries*), were also recorded.

Khil

Khil caves (Magharat el Khil) is a complex site comprising a group of small caves (Grotte A, B, and C) located in the mouth of the Oued Achakar, in the Atlantic coast of the Tangier area (Fig. 3). The caves were initially occupied during the Neolithic but they have been re-used as a corral until very recently. The first archaeological activities were carried out in Grotte A by H. Hencken in 1947 and, later, at Grotte A, B, and C in 1958, by A. Jodin (1958-59). As a result of these works, two Neolithic stages were identified: an earlier level with Cardial and Channeled wares; and a later stage characterized by the presence of Ashakar ware (Gilman, 1975). In 2011 Grotte C and B were re-excavated by a Spanish-Moroccan team within the AGRIWESTMED project. The materials analyzed in this paper were collected during the 2011 excavations (Peña-Chocarro et al., 2013 a).

In Grotte B, a trench of 4 m^2 and 90 cm deep was excavated. In the deepest part of the stratigraphy we recorded Early Neolithic levels dated to the late 6th millennium cal. BC (SU 2009 and SU 2010) and above them, Middle Neolithic levels dated to the mid-late 5th millennium cal. BC. In the upper part more recent and mixed material was identified (SU 2001-2002).

In Grotte C, excavations focused on a profile located in the eastern wall of the cave (Fig. 3). A series of Early Neolithic layers dated to the late 6th millennium cal. BC (SU 18 to 15) with Cardial ware were located above the base of the cave. Immediately above, Middle Neolithic levels dated to the 5th millennium cal. BC with Achakar ware (SU 14 to 12), which are thought to be contemporaneous with the occupation of Grotte B, were recorded. The upper part of the stratigraphy contained mixed materials and evidence of disturbance by animals such as hares, porcupines or foxes.

Abundant evidence of shellfish (mostly Patellidae) and fish (Sparidae) were documented in both Grotte B and C suggesting that the inhabitants of the cave collected seafood, although small quantities of bones of domestic animals such as ovicaprids and pigs were also identified pointing to a broader spectrum economy.

Ifri Oudadane

Ifri Oudadane is a rock shelter approximately 5 m high and 15 m wide located in a coastal marble cliff near Nador, in the Eastern Rif (Fig. 4). The site was discovered recently during road works in the area and it has been excavated since 2006 by a Moroccan-German team ("Eastern Rif" project) which includes the participation of the *Institut National des Sciences de l'Archéologie et du Patrimoine du Maroc* (INSAP), the *Kommission für die Archäologie Außereuropäischer Kulturen des Deutschen Archäologischen Instituts* (KAAK) and the University of Cologne (Jebb, 2008; Linstädter, 2004, 2010; Mikdad et al., 2000; Moser, 2003; Nami, 2007; Nami and Moser, 2010).

Four campaigns of excavation have been carried out in 2006, 2007, 2010 and 2011 (Fig. 4). During the 2006 and 2007 seasons, the sediment was dry sieved and few macro remains were retrieved. However, in 2010 and 2011 the totality of the sediment was floated and a rich assemblage of cultivated and wild plant remains was recovered. Results from the 2010 season have been already published (Morales et al., 2013). The data presented in this paper derived from the unpublished 2011 season.

The stratigraphy of the cave is divided into two clear occupation periods (Linstädter and Kehl, 2012). The deepest level covers the Epipalaeolithic period. It is a 100 cm thick layer where bone fragments of wild animals (e.g. *Ammothragus lervia*) and lithic tools were retrieved. Three radiocarbon dates on seeds of *Chamaerops humilis* from this period are available; the oldest dates go back to 9028 ± 41 BP (Beta-313468) while the youngest to 7632 ± 29 BP (Beta-316137). The upper part of the stratigraphy forms a 1.5 m thick deposit including ash lenses with significant amounts of charcoal. Pottery fragments and bones of domesticated animals are present indicating an Early Neolithic occupation.

Based on the radiocarbon dates, the Neolithic occupation can be divided into three archaeological sub-layers: the Early Neolithic A, a 20 cm thick deposit containing material (bone fragments of domesticated ovicaprines). Two radiocarbon dates are available covering a time span between 5600-5300 cal. BC. The Early Neolithic B is the major occupation phase with ten radiocarbon dates ranging between 5100 and 4700 cal. BC. This part of the stratigraphy yielded the richest Early Neolithic assemblage including retouched blades, impressed pottery and bone fragments of domesticated species. The Early Neolithic C is the last unit of the deposit. It contains very few artifacts with dates ranging from 4600 to 4400 cal. BC (Linstädter and Kehl, 2012; Morales et al., 2013).

3. Material and methods

Macrobotanical remains, including seeds and fruits, were collected from the sediment of the excavations by floating each soil sample and then sieving the flots (light fraction) using a column of sieves with a mesh size of 4 mm, 2 mm, 1 mm and 0.5 mm. The totality of the sediment retrieved from the three sites was fully analyzed, but the amount of sediment varies depending on each site. The volume of the soil sampled for each site is showed in Table 1.

Plant remains are preserved through carbonization and they have been identified using a binocular microscope (8-80x magnification). Identification has been carried out by comparison with modern specimens from the seed reference collections of the Archaeobiology Lab of the Spanish National Research Council at Madrid and the Department of Historical Sciences, University of Las Palmas de Gran Canaria (Spain),

and by consulting specialized literature on plant anatomy. Botanical nomenclature for crops follows traditional binomial classification (see Zohary et al., 2012 for their modern grouping based on cytogenetic and molecular affinities), while for the wild plants we have followed Fennane et al. (2007) and Charco (2001).

Seeds of domesticated species were selected for radiocarbon dating; three specimens from KTG, five from Khil, and one from Ifri Oudadane (Table 2). AMS C^{14} dating was carried out at Beta Analytics. The corrected age was calibrated using IntCal13 (Reimer et al., 2013) and OxCal 4.2.4 (Bronk-Ramsey, 2009). All the dates are given in calibrated years BC unless otherwise stated.

4. Results

Charred remains of South-Western Asian crops were recorded in the three sites analyzed. A total of 2653 seeds of domesticated plants were identified, of which 236 were retrieved in KTG, 2323 in Khil, and 38 in Ifri Oudadane. Among the domesticated plant remains we have identified cereals and pulses. In addition, wild plants were also recorded in the samples. Table 1 shows the estimated number of plant macrofossils in each site while a complete table with full results by sample is provided in the on-line Supplementary material 1, 2, and 3. Images of the most significant plant taxa are showed in Fig. 5.

4.1 Cereals

Among the cereals we have identified five taxa that include emmer (*Triticum dicoccum*), hulled wheat (*T. monococcum/dicoccum*), free threshing wheat (*T. aestivum/durum*), barley (*Hordeum vulgare*) and naked barley (*H. vulgare* var. *nudum*).

Emmer (*Triticum dicoccum*) is relatively frequent and it has been recorded in KTG and in Khil. Remains of emmer comprise grains and spikelet forks (chaff) which has allowed an accurate identification of the remains. Emmer is abundant in KTG with 67 grains, while in Khil only three seeds have been recorded. At KTG four grains were identified as hulled wheat (*T. monococcum*/ *dicoccum*) as it was not possible to distinguish between these two species. A grain fragment of einkorn (*Triticum monococcum*) was identified from previous excavations at KTG (Ballouche and Marinval, 2003); however we could not identify this cereal in the samples from the 2012 season.

Grains from free-threshing wheat are present in all sites analyzed, being more abundant in KTG (no=42). Only 10 grains were recorded in Khil and seven in Ifri Oudadane. Grains from hard wheat (*T. durum*) cannot be consistently distinguished from bread wheat (*T. aestivum*) based on morphological characters (Zohary et al., 2012). Here we have grouped both species in the category of free-threshing wheat (*T. aestivum/durum*), although it is possible that these grains belong to *T. durum* since no records of *T. aestivum* rachis segments from Neolithic sites of North-Western Africa are available yet (Morales et al., 2013).

Barley (*Hordeum vulgare*) has been recorded in KTG and Ifri Oudadane, although this species is less common than wheat. Only grains are present while chaff remains are absent. In two grains from KTG and three grains from Ifri Oudadane it was possible to observe the characters of naked barley (*H. vulgare* var. *nudum*) (Fig. 5). The poor preservation of the remaining barley seeds has prevented a precise identification, but it

must be highlighted that hulled barley (*Hordeum vulgare* subsp. *vulgare*) has not been identified whatsoever in Neolithic sites of Morocco.

4.2 Legumes

Domesticated legumes have been recorded in Khil and Ifri Oudadane. Three species aree present: broad bean (*Vicia faba*), lentil (*Lens culinaris*), and pea (*Pisum sativum*).

Broad bean (*Vicia faba*) is the most abundant domesticated plant from the three sites analyzed here, although most of the remains (no=2237) come from Khil. Only one fragment of a seed of *V. faba* was identified at Ifri Oudadane. In the case of Khil, broad beans (*V. faba*) were found on high densities in samples from the Early Neolithic of the Grotte C, being less common in later levels and in the Grotte B.

Peas (*Pisum sativum*) have been documented in Khil and Ifri Oudadane. A unique seed was identified at Khil (Grotte C) and 6 seeds at Ifri Oudadane. Lentils (*Lens culinaris*) are only present at Ifri Oudadane. Three seeds of this species were found in the Early Neolithic A sub-layer of this site.

4.3 Wild plants

Seeds from wild plants have been documented in all three sites. At Ifri Oudadane they are especially abundant (no= 7263), while at Khil and KTG they are rare (Table 1). The most abundant are *Pistacia lentiscus*, wild legumes and *Chamaerops humilis*, among many others. Some of these species produce edible fruits and could have been used as food for either humans or animals while other taxa may represent material for basketry (Morales et al., 2013). Additionally, at Ifri Oudadane we have recorded seeds belonging to arable weeds (Table 1). Among them taxa such as *Chenopodium murale*, *Emex spinosa* and *Malva* cf. *parviflora* are the most abundant.

4.4 Radiocarbon dates

A series of ^{14}C AMS dates were obtained on seeds of domesticated plants from the three sites (Table 2). Three cereal grains from Neolithic levels of KTG were dated obtaining the following dates: 6390 ± 30 BP (Beta-331987), 6190 ± 40 BP (Beta-331985), and 5400 ± 30 BP (Beta-331986). Sample Beta-331987 has provided the earliest date for a domesticated cereal in the region, with an age of 5468-5316 cal. BC. In Khil we have dated five seeds of *Vicia faba* and *Triticum aestivum/durum* between 6180 ± 50 BP (Beta-295780) and 5420 ± 40 BP (Beta-316506). At Ifri Oudadane a complete series was obtained for the material analyzed in the 2010 season (Morales et al., 2013), so it was decided to date only one seed from the 2011 season, a pea (*Pisum sativum*) from the Early Neolithic A level dated to 6160 ± 30 BP (Beta-341129). All dates from Neolithic levels fall within the ~5500-4000 cal. BC interval (see calibrations in Table 2). They indicate a remarkable degree of internal consistency in each site, with the samples occurring in correct stratigraphic order and with no apparent inversions.

5. Discussion

5.1 Agriculture in Morocco between 5500 and 4000 cal. BC

Results from the analysis carried out at the sites of KTG, Khil, and Ifri Oudadane prove the preservation of cultivated plant remains in Neolithic layers. Although the number of sites studied is low, the application of systematic sampling and recovery has

allowed obtaining enough material for direct dating providing, thus, information on both the species used at each site and the first farming practices carried out in northern Morocco.

All the plant remains recorded were preserved by charring which usually occurs when seeds get in contact with fire during processing (roasting, parching, etc.) or when they are turned into waste and thrown away into the fire as result of cleaning activities. Contact with fire could occur at different stages during the processing of seeds for their use (van der Veen, 2007).

In KTG, crop remains include cereal grains, mostly indeterminate wheat (no=96; 45 % of crops), emmer (no=67; 31 % of crops) and free-threshing wheats (no=41; 19 % of crops), with only one remain of chaff (a single spikelet fork from *Triticum dicoccum*) and no arable weeds. High values of chaff and low numbers of grains is typical of early processing stages; on the contrary, low numbers of chaff and high number of grains is characteristic of late processing stages or final products (van der Veen, 2007). Low numbers of wild plants also indicate a late processing stage, since most seeds of wild plants are discarded during early processing stages. The absence of weeds and the low number of chaff at KTG suggests that these samples probably represent late processing stages (grain cleaning), food refuse or small accidents during cooking. Early processing activities could have been carried out at other locations not sampled yet or in the crop fields.

The seed assemblage from Khil consists of a large concentration of broad bean (*Vicia faba*) seeds (no=2237; 96 % of crops) which were retrieved from the Early Neolithic layers of Grotte C and a few grains of free-threshing wheats and barley scattered through the stratigraphy. In addition, a possible seed of emmer wheat was also identified in the earliest Neolithic level. Instead, Grotte B has yielded a single grain of wheat (*Triticum* sp.) together with 6 broad beans (*Vicia faba*). The higher concentration of broad beans comes from Grotte C and particularly from Stratigraphic Unit 15 which shows a concentration of 29 seeds per litre of sediment (Supplementary Materials 2). This high number may be the result of an accidental episode of burning of stored seeds, with some seeds spreading over neighboring layers. Nevertheless, *V. faba* is recorded through all the sequence in both Grotte B and Grotte C and this represents, perhaps, a significant cultivation of this species during the Neolithic occupation of the caves. Chaff and field weeds are absent. In terms of farming practices, the composition of the assemblage from Khil is similar to that of KTG probably representing late processing stages, food refuse or small accidents during cooking.

The plant assemblage from Ifri Oudadane is characterized by the abundance of wild plant seeds across the whole sequence from the Epipalaeolithic to the Neolithic (no=7061; 96 % of total seeds). The most common taxa are *Pistacia lentiscus*, wild legumes (*Lathyrus*/*Vicia* sp.), and dwarf palm (*Chamaerops humilis*), but other potential food plants such as acorns (*Quercus* sp.) or wild olive (*Olea europaea*) have been also recorded. Crops are scarce (no=38; less than 1 % of seeds) but present since the earliest Neolithic, with barley (no=13; 34 % of crops) and wheat (no=11; 28 % of crops) being the most abundant. No chaff remains were found, although seeds of arable weeds were present in the Neolithic layers (no= 202; 8 % of seeds). Seeds belonging to this group grow commonly in crop fields and they were probably introduced into the cave accidentally as part of the harvest. A further possibility relates to their inclusion in droppings from domesticated animals, either as a result of grazing or as part of fodder.

Data from pollen and wood charcoal suggests, in fact, the use of the cave for penning flocks during the Neolithic (Zapata et al., 2013).

Although the analysis of the three sites shows a quite homogeneous picture throughout the Neolithic sequence, some differences can be observed regarding the abundance of remains and the diversity of crop species represented (Fig. 6 and Table 1). For instance, at KTG the number of crop seeds (no= 210) and variety of crop species (*Triticum dicoccum, T. aestivum/durum, and Hordeum vulgare*) is higher during the earliest levels, dated to the mid-late 6th millennium cal. BC while later, during the mid-late 5th millennium cal. BC, only 8 cereal grains (*Triticum aestivum/durum* and *Hordeum vulgare*) were retrieved being emmer wheat absent. A similar pattern was recognized at Ifri Oudadane, where free-threshing wheats (*Triticum aestivum/durum)* and legumes (*Lens culinaris, Pisum sativum* and *Vicia faba*) have been only recorded in the Early Neolithic A and B whereas the Early Neolithic C layers have only produced two grains of barley (*Hordeum vulgare*). For Khil, most crop seeds (no=2242) were recovered from the Early Neolithic levels. In the later Neolithic layers the number of crop seeds is reduced to 16, although the number of taxa is quite similar throughout the Neolithic sequence.

In other words, the earliest layers dated between the mid-late 6th millennium cal. BC and the early 5th millennium cal. BC are richer in domesticated species (both in the number of remains preserved and the variety of species represented). What is more, crop assemblages from the mid-late 5th millennium cal. BC are smaller and less diverse, showing a general trend towards a decrease in diversity and a focus to the cultivation of free-threshing wheats and barley, emmer being absent (Fig. 6 and Table 1).

The lost in crop diversity during the 5th millennium cal. BC have been also recorded in areas of Europe such as the Iberian Peninsula (Pérez Jordà and Peña-Chocarro, 2013; Pérez Jordà et al., in press), France (Gassin et al., 2010), and Italy (Arobba and Caramiello, 2006; Nisbet, 2008), although in the northern part of Italy the evidence of free-threshing wheat increase is less evident than in the south (Rottoli and Castiglioni, 2009). The reduction in agricultural diversity has been linked in the Iberian Peninsula and Central Europe to a possible change in the agrarian model; a shift from more intensive farming that characterized the earliest Neolithic to a more extensive farming in later periods, with the possible introduction of manure and animal traction (Antolín et al., 2015, Bogaard, 2004; Bogaard and Jones, 2007; Bogaard et al., 2013; Kreuz et al., 2005; Martínez Sánchez, 2013; Pérez Jordà and Peña-Chocarro, 2013; Pérez Jordà et al., in press).

The evidence from Morocco is still limited as only three sites have been analyzed so there is not enough information to infer any change in the production model here. Environmental conditions in the later Neolithic seem to suggest a gradual process of desiccation in the region (Linstädter, 2008; Zapata et al., 2013) which may suggest that in Northern Morocco the reduction in crops and farming importance may have different causes, including climatic ones. However, further research is still necessary in order to understand the evolution of farming practices in the region.

5.2 Arrival of the first South-Western Asian domesticated plants to North-Western Africa

The macro-botanical remains presented in this paper constitute the largest and better-contextualized assemblage of South Western Asian plants in North-Western Africa and provide an excellent opportunity to discuss the arrival of the first domesticated plants into this region. According to the results obtained, the Neolithic crop package introduced in the northern coast of Morocco was made of cereals (*Triticum dicoccum*, *T. aestivum/durum*, and *Hordeum vulgare*) and legumes (*Vicia faba, Pisum sativum* and *Lens culinaris*). Both groups are recorded in all the sites except in KTG where no pulses have been retrieved during our excavations, although broad bean (*Vicia faba*) and other legumes were recorded in previous excavations (Ballouche and Marinval, 2003). The range of crops identified is not homogeneous and each site presents a different combination of plants. Emmer (*Triticum dicoccum*) is the most abundant cereal during the Early Neolithic, along with free-threshing wheats (*Triticum aestivum/durum*) that is also common, especially at Ifri Oudadane. The presence of barley (*Hordeum vulgare*) is more irregular, being frequent at Ifri Oudadane but rare at KTG.

Data obtained from radiocarbon dates on crop seeds indicate that the arrival of South-Western Asian plants into northern Morocco took place around 5500-5000 cal. BC. Cereals and pulses dated to the mid-late 6th millennium cal. BC are present in KTG (*Triticum dicoccum* = 6390 ± 30 BP {Beta-331987}), Khil (*Vicia faba* = 6180 ± 50 BP {Beta-295780}), and Ifri Oudadane (*Pisum sativum* = 6160 ± BP {Beta-341129}), suggesting that the Neolithic crop assemblage arrived as a package including cereals and legumes from the beginning of the Neolithic. Bones of domestic animals and pottery fragments have been also recorded in the same Neolithic layers indicating that domestic animals and plants of South Western Asian origin were introduced in Northern Morocco as part of the same diffusion process.

Archaeobotanical data and radiocarbon dates confirm the results obtained in previous seasons at both Ifri Oudadane (Morales et al., 2013) and KTG (Ballouche and Marinval, 2003), where the same set of domesticated plants was identified. Earlier (mid-late 6th millennium cal. BC) radiocarbon dates on crop seeds were obtained from seed material from previous seasons (Ballouche and Marinval, 2003). In addition, it should be remembered that an early date of 6740 ± 50 BP (Beta-295779) was obtained for a domestic lentil recovered in Early Neolithic levels of the 2010 season at Ifri Oudadane (Fig. 7). This is the oldest date for a macro-botanical remain of a domesticated plant in Northern Africa (Morales et al., 2013). However, since the archaeobotanical record from the lower part of the Neolithic sequence at Ifri Oudadane has not yielded any further cereal or pulse remain during the 2011 season, we should be cautious about this very early date until further data is available (see discussion in Morales et al., 2013). Nevertheless, radiocarbon dates on crops from Early Neolithic levels (Fig. 7) overlap on the calibration curve and can be considered roughly contemporaneous, so here we propose that the introduction of South-Western Asian domesticated plants in northern Morocco can be attested in the interval between 5500-5000 cal. BC agreeing with the emergence of the first domestic animals, while earlier dates should be handled with caution until further data are available.

The current data suggests that plant remains from sites in northern Morocco represent the earliest evidence of agriculture in North-Western Africa. No other macro-botanical remains of South-Western Asian crops have been recovered from Neolithic levels in Morocco, neither from Algeria, nor fromTunisia. It is clear that the failure in applying systematic recovery techniques for plant remains in early sites from the region

has influenced research into early agriculture reducing the chances to record Neolithic crops. Nevertheless, recent excavations where systematic sampling has been carried out in Tunisia (Mulazzani, 2013) and Algeria (Roubet, 1979) did not provide remains of domesticated plants. On the contrary, the analysis have yielded abundant remains of wild species, such as acorns (*Quercus ilex*), wild legumes (*Vicia* sp.), and pine nuts (*Pinus pinaster*), that indicate an important role of wild plants in the human diet during this period (Morales et al., 2015; Roubet, 1979).

No African crops, such as sorghum *(Sorghum bicolor*) or pearl millet (*Pennisetum glaucum*), have been identified in Neolithic layers. The domesticated plants identified in sites from northern Morocco come from South Western Asian (Zohary et al., 2012). The lack of evidence of Neolithic farming in other North African regions suggests that the first crops may have arrived in the area through a maritime route, more likely from the Central Mediterranean (Italy) or the South-Western Mediterranean (Iberian Peninsula). The spread of agriculture in Italy took place between 6000-5500 cal. BC (Zohary et al., 2012), while in the Iberian Peninsula the first crops appeared a bit later, between 5700-5200 cal. BC (Antolín et al., 2015; Martins et al., 2015; Peña-Chocarro and Zapata, 2010; Pérez-Jordá et al., in press; Zapata et al., 2004). In the Iberian Peninsula, several sites in the Andalusia region, facing the Moroccan coast, have yielded domesticated plants dated to ~5300 cal. BC (Martínez-Fernández et al., 2010; Peña-Chocarro et al., 2013 b; Pérez-Jordà et al., 2011).

Comparison between dates carried out on seeds from northern Africa and the South of the Iberian Peninsula attributed to the mid-late 6th millennium cal. BC suggests that the spread of agriculture on both sides of the Western Mediterranean coasts could have been a more or less simultaneous process (Linstädter et al. 2012; Morales et al., 2013). The range of plants cultivated in the Iberian Peninsula and in northern Morocco is similar, although the number of crops is lower in Morocco, which lacks several taxa recorded at Iberian sites such as flax (*Linun usitatissimum*), grass pea (*Lathryus sativus/cicera*) or poppy (*Papaver somniferum*) (Morales et al., 2013). Their absence in Morocco may be explained as result of macro-botanical evidence being much more reduced here. In the Iberian Peninsula sampling has been applied systematically to a larger number of sites, and there is more information available (Antolín et al., 2015; Peña-Chocarro and Zapata, 2010; Zapata et al., 2004; Pérez Jordà et al., in press). In Morocco, current data is limited to three sites, located in the northern coast so further research is necessary in other regions of Morocco in order to fully record the whole Neolithic set of crops and to understand the spread of farming through the region.

6. Conclusions

The results presented in this paper confirm that systematic sampling and processing by flotation has been an efficient method to obtain direct data about the presence of domesticated plants at Moroccan Neolithic sites. The analysis and radiocarbon dating of the macro-botanical remains carried out here have provided the largest dataset of South-Western Asian crops in the Neolithic of North-Western Africa. However, the representativeness of the data is still limited to the few analyzed. Future studies should focus on the southern and inland regions of Morocco, where data on the arrival of Neolithic crops is still missing. Special efforts should also be made to research into late Neolithic contexts for which less investigation has been carried out.

Our analyses show that the earliest South-Western Asian crops, along with domesticated animals and pottery, arrived to Morocco between 5500-5000 cal. BC. The assemblage of crops was composed by cereals (emmer, free-threshing wheat, naked barley) and pulses (lentil, peas, broad bean), which were possibly introduced from the Central or Northern Mediterranean shores through a maritime route. Differences in the main crops were found in the sequences analyzed, with a marked decrease in crop diversity that suggest a shift in the agricultural practices between 4500-4000 cal. BC.

Although plant remains are scarce and the conclusions still preliminary, the archaeobotanical evidence from Neolithic sites is very promising and it encourages future research at new sites in the North-Western African region.

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Caption tables

Table 1. List of macro-botanical remains collected from archaeological levels at Kaf Taht el-Ghar, Khil, and Ifri Oudadane; with numbers of seeds unless otherwise stated. Epipaleo.=Epiapalaeolithic; Early Neo.=Early Neolithic.

Table 2. AMS dates on macro-botanical remains from Kaf Taht el-Ghar, Khil, and Ifri Oudadane. Calibrated with IntCal13 (Reimer et al., 2013) and OxCal 4.2.4 (Bronk-Ramsey, 2009).

Caption figures

Figure 1. Location of sites mentioned in the text.

Figure 2. The rock shelter and stratigraphy of Kaf Taht el-Ghar.

Figure 3. The rock shelter and stratigraphy of Khil.

Figure 4. The rock shelter and stratigraphy of Ifri Oudadane.

Figure 5. Macro-botanical remains of domesticated plants: a. *Triticum dicoccum*, emmer (Kaf Taht el-Ghar), b. *Triticum aestivum*/*durum*, free-threshing wheat (Kaf Taht el-Ghar), c. *Hordeum vulgare* var. *nudum*, naked barley (Ifri Oudadane), d. *Vicia faba,* broad bean (Khil), e. *Pisum sativum*, pea (Khil), f. *Lens culinaris*, lentil (Ifri Oudadane). Scale bar is one millimeter.

Figure 6. Percentage of crops according to sites and chronological stages. KTG=Kaf Taht el-Ghar; IO=Ifri Oudadane. Dates are giving in calibrated years BC.

Figure 7. Model of calibrated age ranges constructed with dates of domestic plants in the three sites analyzed: Kaf Taht el-Ghar, Khil and Ifri Oudadane. Determinations on samples from Ifri Oudadane 2010 (Morales et al., 2013) are also included. Radiocarbon ages are calibrated using IntCal13 (Reimer et al., 2013) and OxCal 4.2.4 (Bronk-Ramsey, 2009). KTG= Kaf Taht el-Ghar; IO=Ifri Oudadane.

Caption supplementary material

Supplementary material 1. Complete list of macro-botanical remains collected from archaeological levels at Kaf Taht el-Ghar.

Supplementary material 2. Complete list of macro-botanical remains collected from archaeological levels at Khil.

Supplementary material 3. Complete list of macro-botanical remains collected from archaeological levels at Ifri Oudadane. Epi=Epipalaeolithic; ENA=Early Neolithic A; ENB= Early Neolithic B; ENC=Early Neolithic C.